

THE DISTRIBUTION OF THE CANE TOAD, *BUFO MARINUS*, IN AUSTRALIA AND ITS EFFECTS ON INDIGENOUS VERTEBRATES

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ABSTRACT

Bufo marinus was released in cane growing districts of Bundaberg, Mackay, and northeastern Queensland in 1935 and 1936. At present this species occurs in eastern Queensland and northeastern N.S.W. between Coen and Ballina, across Cape York Peninsula south of Coen, and widely in northwestern Queensland. It is highly toxic to several native vertebrates and the results of moulting or ingestion of *Bufo marinus* by thirty-three native species are summarised.

Bufo marinus occurs naturally in North and South America between southern Texas and central Argentina (Mungomery 1936, p. 72). It has been used as a biological control of insects, snails and rats (Honegger 1970, p. 453) and has been introduced to southern Florida and Louisiana, most islands of the Caribbean, Hawaii, and many western Pacific islands. A consignment of *Bufo marinus* from Hawaii was released in sugar cane growing districts of northeastern Queensland in June, 1935' . . . giving definite promise of yielding some permanent measure of relief in many of the (cane growing) areas stricken by 'white grubs' (larvae of the Grey back Beetle, *Dermolepida albobirtum* Waterhouse and the Frenchi Beetle, *Lepidiota frenchi* Blackburn) . . .' (Mungomery 1936, p. 63). In late 1935 the introduction of the species beyond the Cairns–Tully area, northeastern Queensland was banned briefly but *B. marinus* was soon released in other sugar cane growing districts between Mossman, northeastern Queensland and Isis, southeastern Queensland (Mungomery 1937, p. 12).

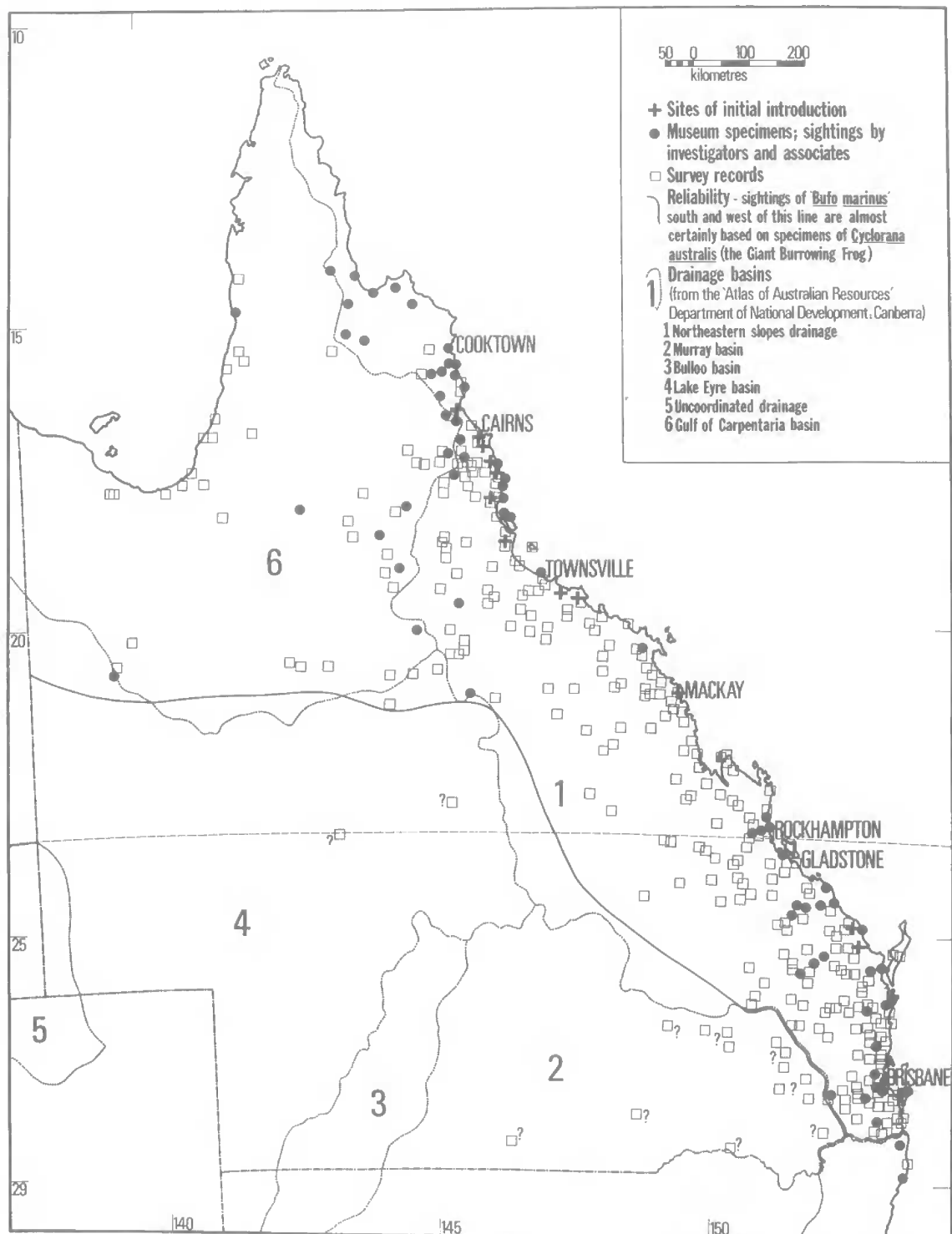
Although some local protests were made prior to the introduction of *Bufo marinus* into Australia, it was not until 1938 that doubts about the wisdom of this introduction were published. Kinghorn (1938, p. 411) suggested that ' . . . it would . . . have been wiser to postpone liberation of the toads until more searching inquiries . . . had been made.' Such caution was countered by other views and it was seriously suggested that *B. marinus* should be protected to enable it to adapt to its

new environment and control insects, especially pests to sugar cane, as planned. By 1941 it was apparent that the role *B. marinus* was playing in controlling Greyback and Frenchi Beetles in Queensland was a minor one. Greyback Beetles are only rarely in contact with the ground (and hence with *B. marinus*). Contact occurs when a few adults fall from trees after mating, or when females move into cane fields to oviposit. *B. marinus* does not frequent the cane fields at the time of the Frenchi Beetles flights owing to lack of cover in the fields.

In early 1974, following repeated press reports of the spread and potential danger of *Bufo marinus*, we decided to examine the distribution of this animal and some of its effects on the native fauna. Our own observations were supplemented with information gathered from associates, veterinarians, and the return of 2,500 circulars sent, with the cooperation of the Department of Education, to Primary Schools, Secondary Schools, and Primary Correspondence Schools. Other circulars were distributed through the National Parks Branch of the Forestry Department.

DISTRIBUTION

The present known distribution of *Bufo marinus* in Queensland and northeastern New South Wales is shown in Fig. 1. Circulars reporting the presence of *B. marinus* in particular areas were assessed with regard to the possibility of identity confusion with the native Giant Burrowing Frog, *Cyclorana aus-*

FIG. 1: Distribution of *Bufo marinus* in Queensland.

tralis, which is a large species known as a 'toad' in many western areas of Queensland. This assessment has resulted in the reliability line in Fig. 1. Without specimens to confirm extreme western reports of *Bufo marinus*, we assume these reports probably refer to *Cyclorana australis*. *Bufo marinus* and *Cyclorana australis* are compared in Plate 41.

Small numbers of the species have recently been released accidentally ('Time', August 5th, 1974) in the Northern Territory (Darwin) and in Western Australia (Perth). It is not yet known whether these unfortunate introductions will result in the establishment of *B. marinus* in these areas.

It is probable that the spread of *B. marinus* as shown in Fig. 1 was aided by accidental or deliberate transportation by humans. It was used by medical practitioners in pregnancy tests, and was believed to eradicate many species of insects and snakes. Many universities use these animals in large numbers, importing them into areas where they have not yet been established. Private collectors also maintain live *B. marinus* in many cities. Reports of deliberate introductions of *B. marinus* to Nambour SE. Q., Fraser Island SE. Q., and Normanton NW.Q. have been received although most correspondents could provide no information on how or when the species first appeared in their areas.

The precise factors controlling the spread of *B. marinus* are not understood. There can be no doubt, however, that temperature, water, food, and availability of shelter, especially during dry periods, are controlling factors. Straughan (1966, p. 230) reports that mating will not occur unless the water temperature reaches 25.6° C. There is no information about minimal water temperature requirements to enable *B. marinus* tadpoles to develop to the stage of metamorphosis but this normally occurs in water 25.6° C and above.

The success of *B. marinus* in establishing itself in Australia is attributable to its adaptability, resilience, high breeding potential, and relative freedom from predators. It has been found in every vegetation zone excluding very high altitude closed forests and extremely arid districts of the far west. Specimens have been observed recently in the following varied habitats—frontal dunes of ocean beaches (Mon Repos, via Bundaberg, SE.Q.; Walker Bay, via Cooktown, NE.Q.); the inland border of coastal mangroves (Amos Bay, via Cooktown); highly acidic areas of coastal wallum (Cooloola, SE.Q.); *Melaleuca* swamps (Cooktown, NE.Q.); open grassland (Marina Plains, near Princess Charlotte Bay, NE.Q.); open sclerophyll forest (Lily Creek, via Cooktown and Mt. Molloy, NE.Q.); highland closed forest (Mt.

Glorious, SE.Q. and Dawes range, ME.Q.); dry, sparse open plains adjoining Mitchell and Morland Rivers, N.Q.; wet or dry creek beds, and towns and cities between Cooktown, NE.Q. and Ballina, NE.N.S.W.

Almost any water is used by *B. marinus* for egg deposition and fertilization. Queensland Museum slide MF321 shows a pair in amplexus and a string of freshly laid eggs in the salt water of Rainbow Beach, Cooloola, SE.Q. No data is available on the survival potential of such eggs but eggs, tadpoles, and newly metamorphosed young have been observed on a tidal flat at Amos Bay, 30km S. of Cooktown (J.C. early 1973; January, 1974). Here water from heavy rain drains across the flat and accumulates in tyre tracks. The whole flat is regularly covered in salt water. *B. marinus* has apparently used the hot, shallow, slightly brackish pools to breed successfully in great numbers although adults have been seen only rarely in the surrounding area. Schultze-Westrum (1970, p. 37) has reported the ability of *B. marinus* in New Guinea to breed in brackish water and to survive water temperatures of 40° C in the larval stage. Straughan (1966, p. 230) notes that *B. marinus* will utilize '... any waterhole, transient pool, ditch, or sluggish creek backwater ...' irrespective of whether the water is clear or muddy, whether water weeds are present or absent, and whether the substrate is of sand, mud or rock. This remarkable adaptability as far as breeding sites is concerned contrasts sharply with the habits of many species of native frogs which are highly selective in their choice of breeding sites.

The high breeding rate of *B. marinus* has also assisted its spread in Queensland. J.H.B. (1936, p. 25) reported the production of 125,000 eggs by nine females in one morning and notes that females may breed more than once in a season. At Barrett's Lagoon 8 km west of Cooktown, NE.Q., at the height of the breeding season in 1970, the shallow edges of the lagoon appeared to be 'alive' with pairs of *B. marinus* in amplexus for several successive nights. Many of the millions of eggs produced in such permanent water presumably develop, metamorphose, and grow to adulthood because they have few predators. In some areas (e.g. Endeavour R., Cooktown, NE.Q.) teeming thousands of newly metamorphosed *B. marinus* have been observed leaving the water and gradually moving into the shelter of grass or flood debris on the banks.

Similarly, its catholic choice of shelter sites indicates that this requirement for establishment is only a minor one. We have seen or collected *B. marinus* from shallow depressions, in logs, drain

pipes, debris, hollows at ends of well constructed burrows (greater than 25cm deep) in soft stony and clayey soils, under cement slabs, rocks, and sheets of roofing iron. Presumably by using these shelters they are able to survive prolonged hot and dry periods in areas of relatively low rainfall (e.g. Laura, Charters Towers, and Mt. Garnet). The remarkable endurance of *B. marinus* to extremes of temperature is demonstrated by individuals which were observed moving slowly away from a bushfire, having survived massive burning (D. Crossman, pers. comm.).

B. marinus also exhibits catholic food habits. Several studies have shown that the major part of the diet of *B. marinus* in Queensland is insects, largely beetles (Mungomery 1936, pp. 63-74; Straughan 1966, p. 322; van Tets and Vestjens 1973, p. 52) but survey circulars indicate that small snakes of several species (including *Amphiesma mairii*), lizards, and frogs are also eaten and recently a small marsupial (*Planigale maculata*) was found in the gut of a toad collected near Samford, SE.Q. (C. Limpus, pers. comm.). These tastes, which include its only known common predator (*Amphiesma mairii*), ensure a food supply for *B. marinus* in any Australian habitat where cold or extreme aridity do not prevent its survival.

Another adaptation facilitating the spread of *B. marinus* is its relative freedom from predation. With the possible exception of the freshwater Snake (*Amphiesma mairii*), which has been reported as eating young *B. marinus* regularly (Lyon 1973, p. 4) and observed eating tadpoles, *B. marinus* has no major predators in Australia. It is a highly toxic species (Meyer and Linde 1971, p. 522). The bulk of the venom is contained in the parotid glands and the skin but much of the remainder of the animal is also apparently toxic to Australian vertebrates.

EFFECTS ON ENDEMIC VERTEBRATES

The effect *B. marinus* has had on endemic vertebrates since its introduction forty years ago cannot be assessed in detail from the data presented here and may never be completely known because little information is available on species populations before 1935 and because so many other possibly detrimental changes have taken place in the environment since *B. marinus* was introduced. Schultze-Westrum (1970, p. 37) in reviewing the effects of *B. marinus* on native New Guinean vertebrates has examined its detrimental effects in terms of (1) predation, (2) food competition, (3) competition for resting places.

Many of the reports of predation upon toads are

inconclusive because the subsequent fate of the predator was not or could not be determined. In the case noted of the Western Native Cat (*Dasyurus geoffroii*), death was not immediate, and it is conceivable that such a predator could be seen to attack a toad, and leave without apparent upset. There is no substantiated evidence that any endemic mammal can prey successfully upon *B. marinus*. We regard *B. marinus* as a potential threat to the existence of some terrestrial endemic predators such as frog-eating snakes and native cats (*Dasyurus* spp.) with which it is sympatric. One of us (M.A.) kept a Western Native Cat (*Dasyurus geoffroii*) in captivity for three years. During this time it was never observed to hesitate in attacking any small vertebrate. Although it often exhibited caution in the method of killing these prey, it never hesitated to bite. It was the result of a single bite (an accidental encounter) on an individual *B. marinus* that caused its death. We have no reason to believe that other individuals of *Dasyurus* spp. would behave any differently if confronted by a toad. It is of interest to note that the only recent undoubted reports of the common occurrence of *D. viverrinus* and *D. maculatus* coming to the attention of the Queensland Museum are from areas where toads are known not to occur (e.g. the Lamington Plateau and the Wyberba district near Stanthorpe).

Predation by toads on some native vertebrates is noted above. The instance of a whole *Planigale maculata* being found in the stomach of a *B. marinus* is not a positive indication of predation. The toad may conceivably have found the animal dead. However, considering that *B. marinus* normally (we have no evidence to the contrary) eats live prey, this record strongly suggests predation.

Competition involving toads concerns food and living space. It is now common, when searching for reptiles and small mammals in some areas of eastern Queensland, to find only *B. marinus*, sometimes in groups, in niches occupied by small native vertebrates in adjoining toad-free areas. *B. marinus* is probably the most common small vertebrate in eastern Queensland and apparently survives where native vertebrates cannot. In late 1973 a search for reptiles on a small island in the partly constructed North Pine Dam near Petrie, southeastern Queensland, was unsuccessful. With the exception of a single *Litoria fallax* there were no native vertebrates on the island. Every log and grass-shaded depression housed numerous adult and young *B. marinus* all of which appeared to be in excellent condition. Competition for and domination of breeding grounds have probably been instrumental in reducing populations of some native frogs along with

clearing of habitats. Reports of the disappearance of certain species of frogs (*Limnodynastes peroni*) and snakes (*Pseudechis porphyriacus*, *Acanthophis antarcticus*, and *Pseudonaja textilis*) following the arrival of *B. marinus* in several areas are too numerous to be ignored although it is impossible to prove *B. marinus* responsible.

EFFECTS OF MOUTHING OR INGESTING *B. marinus*

Kuhlia rupestris (Jungle Perch)

Ingesting; no ill effects. (Remains of *B. marinus* found in gut; observed feeding, Daintree R., NE.Q.—J. Grimes, pers. comm.)

'Jew (= Cat) Fish'*

Ingesting eggs, young; no ill effects.

'Eel' (probably *Anguilla* sp.)*

Ingesting eggs, young; no ill effects. (Populations reported to have been affected adversely initially.)

'Perch'*

Ingesting eggs, young; no ill effects.

Chelodina sp. (Long-necked Tortoise)

Ingesting; no ill effects. (Specimen observed feeding on dead *B. marinus*, Gunn et. al. 1972, p. 110.)

Egernia bungana (Land Mullet)

Mouthing; death. (*B. marinus* entered cage and was apparently bitten on hind leg—R. Latcham, pers. comm.)

Varanus spp. (Goannas)

Ingesting whole; death. (*Varanus* populations reported repeatedly to have declined in numbers. Captive specimen died within a few minutes—P. Douglas, pers. comm.)

Crocodylus porosus (Estuarine Crocodile)

Mouthing whole; no ill effects. (One 2m wild specimen found near Edward R., NW.Q. with *B. marinus* in mouth; *B. marinus* released when specimen captured—J. Bredl, pers. comm.)

Ingesting whole; no ill effects. (Hungry captive specimens have eaten many *B. marinus* reluctantly on several occasions; well-fed specimens refused them—C. Tanner, pers. comm.)

'Carpet Snake' (probably *Morelia spilotes variegata*)*

Ingesting whole; effects not reported. (Reported frequently, but doubtful because *M. spilotes variegata* is normally a mammal and bird eater.)

'Black-headed Python' (probably *Aspidites melanocephalus*)*

Ingesting whole; effects not reported. (Doubtful, normally a reptile and mammal eater.)

Stegonotus cucullatus (Slaty Grey Snake)

Mouthing whole; death. (One specimen found dead with *B. marinus* only partly ingested, near Cairns, NE.Q.—C. Tanner, pers. comm.)

Amphispiza mairii (Common Keelback)

Ingesting eggs, tadpoles, young; no ill effects. (Lyon 1973, p. 4. *A. mairii* thrives in captivity on diet of *B. marinus*—C. Tanner, pers. comm. Only species known to utilize *B. marinus* regularly as food source.)

'Green Grass Snake' (probably Green Tree Snake, *Dendrelaphis punctulatus*)

Ingesting tadpoles, young; no ill effects. (Captive specimen—R. Latcham, pers. comm.)

Boiga irregularis (Brown Tree Snake)

Ingesting whole, whole minus skin; death. (Two adult specimens were force-fed on *B. marinus* minced whole and minus skin; both died overnight—C. Tanner, pers. comm.)

Pseudechis porphyriacus (Red-bellied Black Snake)

Ingesting whole; death. (Populations reported repeatedly to have declined in several areas since arrival of *B. marinus*; Covacevich, 1974, p. 23.)

Acanthophis antarcticus (Death Adder)

Mouthing; death.

Ingesting; death. (Two adults found dead with *B. marinus* partly ingested, Deighton R., NE.Q.—F. Woolston, pers. comm. Populations reported to have declined since arrival of *B. marinus*; Shipton's Flat, via Cooktown, NE.Q.—J. Roberts, pers. comm.; Mt. Molloy, NE.Q.—F. Little, pers. comm.)

Pseudonaja textilis (Brown Snake)

Ingesting; death. (Dead adult found in Bauple State Forest, SE.Q., with *B. marinus* in gut.—D. Crossman, pers. comm. Young *P. textilis* from McIvor R., NE.Q. refused young *B. marinus* in captivity. Populations reported to have declined in some areas following arrival of *B. marinus*, McIvor R., NE.Q.—C. Tanner pers. comm.)

Notechis scutatus (Tiger Snake)

Mouthing; death.

Ingesting; death. (J24594 captive juvenile, died suddenly with *B. marinus* only partly ingested. Clutch of approximately 30 captive young were fed young *B. marinus*; all died overnight, some with 2 *B. marinus* in gut but most with only 1 partly ingested—C. Tanner, pers. comm.)

'Ducks'*

Ingesting young; no ill effects. (Domestic ducks not affected according to survey reports and fowls reported with no ill effects following ingestion. No indication of whether ducks are native or domestic.)

'Ibis'*

Ingesting intestine only; no ill effects.

'Crane'*

Ingesting; no effects reported.

'Swamp Hen'*

Ingesting tongue only; no ill-effects.

'Pheasant'*

Ingesting young; no ill effects.

Corvus sp. (Crow)

Mouthing; death.

Ingesting stomach, tongue, old road killed specimens; no ill effects. (Frauca, 1974, p. 112–4. (Pet *Corvus* sp. died suddenly after pecking *B. marinus*—R. Latcham, pers. comm. Two circulars report the eating of *B. marinus* tongues and stomachs; many report pecking at old road-kills.)

Dacelo gigas (Kookaburra)

Mouthing; death.

Ingesting freshly killed young adults; no im-

mediate ill effects. (O15549, *D. gigas* with *B. marinus* in mouth found dead with no apparent injuries on roadside, Woodgate State Forest, SE.Q. Young freshly killed adult *B. marinus* consumed readily by *D. gigas* at Mt. Nebo, SE.Q.—F. Dale, pers. comm.)

Owl

Ingesting tongue only; no ill effects.

Podargus strigoides (Tawny Frogmouth)

Ingesting; no ill effects. (Filmer 1974, p. 2).

Kite Hawk

Ingesting; no ill effects. (Observed following tractor and eating disturbed *B. marinus*.)

Whistling Kite

Ingesting gut only; no ill effects.

Koel

Ingesting gut only; no ill effects. (Cassels 1970, p. 16).

Hydromys chrysogaster (Water Rat)

Ingesting possibly stomachs only; no ill effects. (Carcasses of *B. marinus* minus stomachs have been found in several areas along river banks. *H. chrysogaster* believed to be predator along Endeavour R., NE.Q.—C. Tanner, pers. comm.; many survey reports.)

Dasyurus geoffroii (Western Native Cat)

Mouthing; death. (Captive individual observed to bite *B. marinus* and drop it. Panting, rapid pulse, tetanic contractions, convulsions, and death in 30 minutes.)

Sarcophilus harrisii (Tasmanian Devil)

Mouthing; death. (Captive specimen—P. Douglas, pers. comm.)

*Reported only in survey circulars.

DISCUSSION

B. marinus has not eradicated the pests it was introduced to control; it is still actively spreading in Australia, and it is not clear what limiting factors will eventually control this spread. It has a deleterious effect on some native vertebrate fauna, which may result in the regional extinction of native terrestrial predators, although several species can apparently ingest *B. marinus* or its remains without ill effects.

At present there is no effective biological control of the species here despite the fact that the snake *Amphiesma mairii* regularly consumes *B. marinus* larvae and young and is common in many of the areas supporting *B. marinus*. Prolonged cold temperatures and frost and, to a lesser extent, dryness may restrict its spread much further into inland Queensland and southern New South Wales. While *B. marinus* has thrived in all the areas to which it has been introduced, there are no records of successful large scale eradication.

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